Eur J Vasc Endovasc Surg (2015) 49, 524–531

Editor's Choice – Ten-year Experience with Endovascular Repair of Thoracoabdominal Aortic Aneurysms: Results from 166 Consecutive Patients

E.L.G. Verhoeven [a,*], A. Katsargyris [a], F. Bekkema [c], K. Oikonomou [a], C.J.A.M. Zeebregts [c], W. Ritter [b], I.F.J. Tielliu [c]

[a] Department of Vascular and Endovascular Surgery, Paracelsus Medical University, Nürnberg, Germany
[b] Department of Radiology, Paracelsus Medical University, Nürnberg, Germany
[c] Department of Surgery, Division of Vascular Surgery, University Medical Center Groningen, University of Groningen, The Netherlands

WHAT THIS PAPER ADDS

This is the largest series in Europe to report longer-term outcomes of endovascular thoracoabdominal aortic aneurysm (TAAA) repair using fenestrated and branched stent grafts. Although endovascular TAAA repair in expert hands is associated with high technical success rate, and remains safe and effective in the mid-term, complications are not rare. Correct patient selection, careful planning, team effort, and technical success are needed to provide the best possible outcome for the patients. The re-intervention rate is not low, but most re-interventions can be performed by endovascular means.

Objective: To present a 10 year experience with endovascular thoracoabdominal aortic aneurysm (TAAA) repair using fenestrated and branched stent grafts.

Materials and methods: Consecutive patients with TAAA treated with fenestrated and branched stent grafts within the period January 2004–December 2013. Data were collected prospectively.

Results: 166 patients (125 male, 41 female, mean age 68.8 ± 7.6 years) were treated. The mean TAAA diameter was 71 ± 9.3 mm. Types of TAAA were: type I, $n = 12$ (7.2%), type II, $n = 50$ (30.1%), type III, $n = 53$ (31.9%), type IV, $n = 41$ (24.8%), and type V, $n = 10$ (6%). Fifteen (9%) patients had an acute TAAA (11 contained rupture, 4 symptomatic). One hundred and eight (65%) patients were refused for open surgery earlier. Seventy eight (47%) patients had previously undergone one or more open/endovascular aortic procedures. Technical success was 95% (157/166). Thirty day operative mortality was 7.8% (13/166), with an in hospital mortality of 9% (15/166). Peri-operative spinal cord ischemia (SCI) was observed in 15 patients (9%), including permanent paraplegia in two (1.2%). Mean follow up was 29.2 ± 21 months. During follow up 40 patients died, two of them probably from aneurysm related cause. Re-intervention, mostly by endovascular means, was needed in 40 (24%) patients. Estimated survival at 1, 2, and 5 years was 83% ± 3%, 78% ± 3.5%, and 66.6% ± 6.1%, respectively. Estimated target vessel stent patency at 1, 2, and 5 years was 98% ± 0.6%, 97% ± 0.8%, and 94.2% ± 1.5%, respectively. Estimated freedom from re-intervention at 1 and 3 years was 88.3% ± 2.7%, and 78.4% ± 4.5%, respectively.

Conclusions: Endovascular repair of TAAA with fenestrated and branched stent grafts in high volume centers appears safe and effective in the mid-term in a high risk patient cohort. A considerable reintervention rate should be acknowledged, however.

Article history: Received 29 August 2014, Accepted 28 November 2014, Available online 17 January 2015

Keywords: Aortic aneurysm, Branched, Endovascular repair, Fenestrated, Thoracoabdominal

INTRODUCTION

Thoracoabdominal aortic aneurysms (TAAA) represent a challenge for vascular surgeons. Conventional open repair continues to be associated with remarkable mortality and morbidity, despite improvements in intra- and post-operative care.[1] In 2003, a nationwide database from the USA including 1542 patients reported in hospital post-operative mortality of 22.3% following elective TAAA open repair. Even higher rates were observed for low volume surgeons and hospitals.[2] Post-operative morbidity is also significant, including respiratory insufficiency with prolonged ventilation, cardiac complications, and acute renal failure.[2] In addition, there is an inherent risk for paraplegia depending on the extent of the aneurysm and its repair. In

DOI of original article: http://dx.doi.org/10.1016/j.ejvs.2015.02.013

* Corresponding author. E.L.G. Verhoeven, Department of Vascular and Endovascular Surgery, Paracelsus Medical University, Klinikum Nürnberg, Breslauer Strasse 201, 90471 Nürnberg, Germany.
E-mail address: eric.verhoeven@klinikum-nuernberg.de (E.L.G. Verhoeven).

1078-5884/© 2014 European Society for Vascular Surgery. Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ejvs.2014.11.018

recent years, few selected high volume centers have achieved operative mortality rates of less than 10% with open repair.[3,4] Nevertheless, the composite adverse outcome, defined as operative death, renal failure requiring dialysis, stroke, or paraplegia/paraparesis, remains high at 15.9%.[3,4]

Endovascular techniques have demonstrated short-term advantages in abdominal aortic aneurysm (AAA) repair, and have gradually evolved to address more complex AAA and TAAA, using fenestrated and branched stent grafts.[5–9] Early results of endovascular repair of TAAA in the first 50 patients from the present study group have been published previously.[10] The present report discusses the 10 year experience in 166 consecutive TAAA patients treated with fenestrated and branched stent grafts.

MATERIALS AND METHODS

All consecutive patients with TAAA treated with fenestrated or branched stent grafts under the guidance of the senior author within the period January 2004—October 2009 at one institution, and within the period November 2009—December 2013 at a second institution, were included in this study. Patients with post-dissection TAAA were also included. Patients with suprarenal AAA treated with fenestrated/branched grafts, even if including all four visceral vessels, were excluded. Data were prospectively collected. Endovascular repair as a technique was approved by the institution's ethical committee and all patients provided their informed consent.

Aneurysm morphology was assessed by thin cut ($\leq$1.5 mm) spiral computerized tomography angiography (CTA) with axial and coronal reconstructions. The physical status of all patients was assessed preoperatively with the American Society of Anesthesiologists (ASA) score. The indication for treatment was maximum aortic diameter $\geq$60 mm, except in the case of localized disease. Symptomatic or ruptured TAAA were not excluded.

Stent grafts

Stent grafts were customized based on the Cook Zenith system (William A. Cook Australia, Ltd., Brisbane, Australia), fitting fenestrations and/or branches for the visceral vessels according to pre-operative CTA measurements. Three types of stent grafts were used depending on the aortic anatomy and aneurysm morphology: stent grafts with (A) fenestrations only, (B) branches only, or (C) branches and fenestrations. The planning of fenestrations and branches was based on the anatomy of the target vessels. Fenestrations were preferred for right angle take off visceral arteries (more common in renal arteries), and when the stent graft body was against the aortic wall. Branches were preferentially planned in larger aortic diameters, when the graft was not against the aortic wall, and when the target vessels had a downward path (often in the celiac artery).

The stent grafts had either a distal tube configuration when sealing could be achieved in the abdominal aorta (or within the body of a pre-existing stent graft or surgical graft), or a bifurcated configuration, when landing in the iliac arteries. A proximal and distal sealing zone of at least 20 mm in length was always planned.

Procedure

The procedures were routinely performed either in an angio suite with a fixed imaging system (Artis Zee, Siemens, Erlangen, Germany), or in a hybrid operating room with a fixed imaging system (Artis Zeego, Siemens, Erlangen, Germany). The operation was always done under general anesthesia. Peri-operative cerebrospinal fluid (CSF) drainage was selectively used to reduce the risk of paraplegia. Patients with TAAA type I, II, or III, and patients with previous abdominal aortic surgery were routinely subjected to CSF drainage.

Surgical access was performed via bilateral femoral cut downs in case of stent grafts with fenestrations only, and with an additional access from above (most commonly left axillary artery cut down) in case of stent grafts with fenestrations and branches or branches only. The stent graft deployment technique for fenestrated stent grafts has been previously described in detail.[11,12]

For branched stent grafts, the branched component was introduced through the femoral artery and positioned with the distal edges of the branches 10—20 mm above the ostia of the respective target vessels. After deployment of the branched component, the large femoral sheath was removed, and the arteriotomies temporarily closed (over the stiff guidewire), using snuggers fitted in purse string sutures as previously described.[12] This allowed for the prompt restoration of blood flow to the pelvis and lower limbs. Subsequently, a 45 cm 12F sheath and a coaxial 70 cm 8F or 55 cm 7F sheath were both advanced into the stent graft via the access from above. Each branch and its corresponding target vessel were sequentially catheterized, wired, and stented with a balloon expandable or self expanding covered bridging stent. For fenestrations, balloon expandable Atrium Advanta V12 (Maquet Getinge Group, Hudson, NH, USA) of 22 or 38 mm length were routinely used. For branches, Atrium Advanta V12 of 59 mm were used whenever possible. When a longer covered bridging stent was required, the Fluency (Bard, Murray Hill, NJ, USA) 80 mm stent was used. In branches, both Atrium Advanta V12 and Fluency covered bridging stents were relined with a self expandable stent if there was kinking.

For stent grafts with branches and fenestrations, the fenestrations were usually completed first and followed by the branches as described above.

Technical success was defined as successful deployment of the stent grafts with absence of type I or III endoleak, and patent target vessels. Secondary technical endpoints were reported according to the reporting standards for thoracic endovascular aortic repair (TEVAR) and included procedure time, estimated blood loss, fluoroscopy time, contrast load, and hospital and intensive care unit (ICU) length of stay.[13] Aneurysm sac morphology changes during follow up were classified as follows: aneurysm sac shrinkage (reduction in sac diameter >5 mm), no significant change (−5 to +5 mm), and aneurysm sac expansion (increase in sac diameter >5 mm).[13]

Post-operative management

Post-operatively, patients were monitored with clinical and laboratory examination including thoracic and abdominal X-rays in standardized antero-posterior and oblique views as reference prior to discharge. CTA controls were performed at 1 month, 1 year, and annually thereafter, depending on each patient's characteristics. Suspicion of endoleak or branch vessel malperfusion, was investigated by additional DSA for further evaluation and possible reintervention.

Data analysis

SPSS for Windows (version 20.0; SPSS Inc, Chicago, IL, USA) was used for statistical analysis. Variables are presented as mean ± standard deviation (SD) in case of normal distribution, and median plus range for skewed distribution. Analyzed outcomes included technical success, operative mortality and major morbidity, late events with regard to target vessel stent patency, re-intervention, endoleak, and death. Survival, target vessel stent patency, and re-intervention during follow up were subjected to Kaplan—Meier analysis. A p value of less than .05 was considered statistically significant. To evaluate the effect of the learning curve, the technical success rate in the first 5 years (2004—2008, $n = 21$) was compared with the last 5 years (2009—2013, $n = 145$). To evaluate whether ASA IV patients should receive endovascular repair of TAAA, the early and late mortality of ASA IV patients was compared with that of patients scoring ASA III or less.

RESULTS

Patients

During the study period, 166 patients (125 male, 41 female, mean age 68.8 ± 7.6 years) were treated. Fig. 1 shows the distribution over the years. Patient comorbidities and risk factors are listed in Table 1. Nineteen (11.4%) patients were classified as ASA IV, 120 (72.3%) as ASA III, and 27 (16.3%) as ASA II. One hundred and eight (65%) patients had been refused for open surgery. Seventy eight (47%) patients had previously undergone one or more open and/or endovascular aortic procedures. Fifteen (9%) patients had an acute TAAA (11 contained rupture, 4 symptomatic).

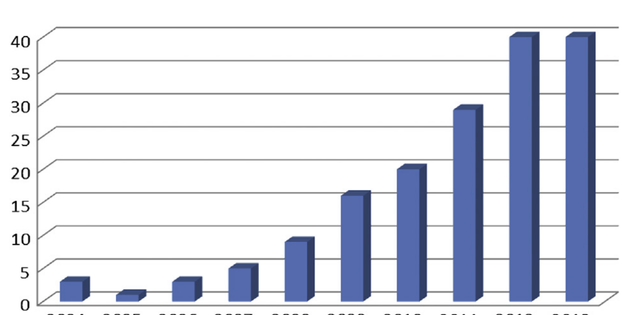


Figure 1. Number of patients treated per year.

Table 1. Pre-operative patient characteristics.

Variable	Patients N (%)
CAD	106 (63.9)
LVEF <45%	35 (21.1)
Hypertension	130 (78.3)
PAD	72 (43.4)
COPD	97 (58.4)
Smoking (current or past)	119 (71.7)
Diabetes mellitus	13 (7.8)
Hypercholesterolemia	132 (79.5)
Serum Cr >100 µmol/L	71 (42.7)
Previous stroke/TIA	10 (6)
Previous aortic surgery	78 (47)
Hostile abdomen	56 (33.7)
ASA ≥III	139 (83.7)
Previous aortic procedure	78 (47%)
Open abdominal aortic surgery	44 (26.5%)
Open thoracic aortic surgery	13 (7.8%)
TEVAR	11 (6.6%)
EVAR	6 (3.6%)
Open thoracic aortic surgery + TEVAR	3 (1.8%)
Open abdominal aortic surgery + TEVAR	1 (0.6%)

CAD = coronary artery disease; PAD = peripheral arterial disease; COPD = chronic obstructive pulmonary disease; TIA = transient ischemic attack; ASA = American Society of Anesthesiologists; LVEF = left ventricular ejection fraction; TEVAR = thoracic endovascular aortic repair; EVAR = endovascular abdominal aortic aneurysm repair.

TAAA characteristics

Mean TAAA diameter was 71 ± 9.3 mm. Types of TAAA according to the modified Crawford classification were: type I, $n = 12$ (7.2%), type II, $n = 50$ (30.1%), type III, $n = 53$ (31.9%), type IV, $n = 41$ (24.8%), and type V, $n = 10$ (6%). Nineteen of the 50 type II TAAA were chronic post type B dissection TAAA.

Fenestrated/branched stent graft configuration

Planned coverage of the aorta from left subclavian artery (LSA) to aortic bifurcation was up to 50% in 40 (24.1%) patients, up to 75% in 76 (45.8%) patients, and up to 100% in 50 (30.1%) patients. In 70 (42.2%) patients a stent graft with fenestrations and branches was used, in 57 (34.4%) a stent graft with branches only, and in 39 (23.5%) patients a stent graft with fenestrations only. The mean number of branches/fenestrations per patient was 3.6 ± 0.8. The total number of planned fenestrations/branches was 600. These included 326 branches (314 downward branches, 8 upward branches, and 4 inner downward branches) and 274 fenestrations. A total of 293 renal arteries, 166 superior mesenteric arteries (SMA), 134 celiac arteries, four left subclavian arteries (LSA), and three left common carotid arteries were targeted.

Operative data

An approach from above was required in 128 (77.1%) patients (left axillary artery: $n = 117$, left subclavian artery: $n = 7$, left brachial artery: $n = 3$, left common carotid

Table 2. Unplanned additional intra-operative maneuvers to achieve technical success.

Procedure type	N (%)
Retrograde target vessel catheterization[a]	7 (4.2)
Iliac covered stent due to iliac artery rupture intra-operatively	2 (1.2)
Femoral artery reconstruction	2 (1.2)
Extra stent grafts because of migration of the proximal aortic tube graft	1 (0.6)
Extra thoracic tube graft + LSA chimney	1 (0.6)
Extra axillary access for renal artery fenestration catheterization[b]	1 (0.6)
Additional TEVAR for rupture	1 (0.6)

[a] Via retroperitoneal surgical approach or laparotomy.
[b] Wire loss from femoral access.

artery, $n = 1$). Cerebrospinal fluid (CSF) drainage was applied in 120 (72.3%) patients.

Fifty-five (33.1%) procedures were performed with a fixed imaging system in an angio suite, and 108 (65.1%) in a hybrid operating room with a fixed imaging system. Three (1.8%) procedures at the early stages of the study, which would normally have been performed in an angio suite, were performed in a conventional operating room with a mobile C-arm, as an extra laparotomy was planned for access.

Technical success

Technical success was achieved in 157 (95%) patients, including 15 patients who required unplanned additional intra-operative maneuvers (Table 2). Technical success was 85.7% for the period 2004—2008 and 95.9% for the period 2009—2013 ($p = .089$). Technical failure occurred overall in nine (5%) patients. In five patients, catheterization of a single target vessel was not possible (4 renal arteries, 1 celiac artery). Of those, one renal artery was revascularized with an ileo-renal vein bypass. In two patients, the bridging stents were implanted too deeply in the renal arteries, resulting in renal artery occlusion. In one patient with a solitary functioning kidney a renal artery rupture occurred because of protrusion of the bridging stent into a small branch of the main renal artery. This was treated with an additional covered stent, but resulted in kidney loss and dialysis. In one patient, a distal graft component was deployed wrongly, and had to be removed via laparotomy, and the procedure aborted. The patient recovered well, but refused a renewed attempt to finish the procedure. She died from myocardial infarct 4 months after the procedure.

Secondary technical endpoints

Mean procedure time was 272 ± 85 min. Median estimated blood loss was 400 mL (range, 100—5000 mL). Median fluoroscopy time was 73 min (range 15—240 min), and median contrast load 210 mL (range 80—500 mL). Median hospital and ICU length of stay were 10 days (range 3—50 days) and 2 days (range 0—42 days), respectively.

Table 3. Thirty day and in hospital mortality.

Cause of death	*N* (%)	Time of death (postop day)
Multiple organ failure	6 (3.6)	1, 2, 5, 8, 9, 68
Intra-operative thoracic aortic rupture	1 (0.6)	1
Acute gastrointestinal bleeding	1 (0.6)	6
Paraplegia, colon ischemia → colectomy → cardiac complications	1 (0.6)	6
Cardiac tamponade	1 (0.6)	Operation day
Subdural hematoma complications after CSF drainage removal	1 (0.6)	30
Peri-operative stroke complications	1 (0.6)	17
Pulmonary embolism	1 (0.6)	10
Respiratory insufficiency with prolonged ICU stay	1 (0.6)	42
Mesenteric ischemia and mesenteric bleeding	1 (0.6)	Operation day

Peri-operative mortality and morbidity

Thirty day operative mortality was 7.8% (13/166), including one patient with a contained rupture. In hospital mortality was 9% (15/166); causes are shown in Table 3. Thirty day operative mortality was 15.8% (3/19) for ASA IV patients, and 6.8% (10/147) for patients with ASA III or less ($p = .17$). Major peri-operative complications are shown in Table 4.

Early re-intervention (≤30 days) was required in 12 (7.2%) patients. These included access artery revision for ischemia or bleeding ($n = 7$), coil embolization for bleeding ($n = 2$; 1 SMA branch, 1 renal artery branch), surgical wound dehiscence repair ($n = 1$), mesenteric hematoma evacuation via laparotomy ($n = 1$), and proximal thoracic stent grafting because of retrograde dissection ($n = 1$).

Table 4. Summary of major peri-operative complications.

Peri-operative complication	*N* (%)
Cardiac complications (MI, arrythmias)	9 (5.4)
Pulmonary insufficiency	6 (3.6)
Renal function deterioration (>30% from baseline)	9 (5.4)
Spinal cord ischemia (SCI)	15 (9)
Permanent paraplegia	2 (1.2)
Temporary paraparesis/paresthesia/urinary incontinence	10 (6)
Permanent paraparesis/paresthesia/urinary incontinence	3 (1.8)
Stroke	2 (1.2)
CSF leakage	1 (0.6)
Bleeding complications	7 (4.2)
Retroperitoneal hematoma	4 (2.4)
Mesenteric hematoma	2 (1.2)
Renal hematoma	2 (1.2)
Access site hematoma requiring revision	1 (0.6)
Colon ischemia	2 (1.2)
Lower extremity ischemia	2 (1.2)
Upper extremity ischemia	4 (2.4)
Brachial nerve injury	1 (0.6)
Groin infection	1 (0.6)
Surgical wound dehiscence	1 (0.6)
Retrograde dissection	1 (0.6)

Follow up

Mean follow up was 29.2 ± 21 months. During follow up 40 patients died. One patient died most probably because of stent graft complications (aorto-esophageal fistula). Another patient with a type IV TAAA died 4 months after the procedure, after being treated for stent graft infection by laparotomy, lavage, and omentoplasty. The remaining patients died of unrelated causes. There was no aneurysm rupture during follow up. Mortality during follow up was significantly higher in ASA IV patients compared with patients with ASA III or less (56.3% vs. 22.6%, $p = .02$). Estimated survival at 1, 2, and 5 years was 83% ± 3%, 78% ± 3.5%, and 66.6% ± 6.1%, respectively (Fig. 2A).

Aneurysm sac shrinkage was noted in 69%, no significant change was seen in 26%, and thee was aneurysm sac expansion in 5% of the patients. Estimated freedom from aneurysm sac expansion is shown in Fig. 2B.

During follow up 22 target vessels occluded, including 15 renal arteries, six coeliac arteries, and one SMA. Renal artery occlusion resulted in permanent dialysis in three patients (2 bilateral renal artery occlusions, 1 solitary kidney). All coeliac artery and SMA occlusions were asymptomatic. Estimated target vessel stent patency at 1, 2, and 5 years was 98% ± 0.6%, 97% ± 0.8%, and 94.2% ± 1.5%, respectively (Fig. 2C).

Late re-intervention (>30 days) was required in 28 patients with a total of 36 events (Table 5). Estimated freedom from re-intervention at 1 and 3 years was 88.3% ± 2.7%, and 78.4% ± 4.5%, respectively (Fig. 2D).

Endoleaks were detected in 33 patients. There were 20 type I/III endoleaks, including three type Ia, 11 type Ib (target vessel; $n = 7$, iliac; $n = 4$), and six type III (target vessel; $n = 4$, aortic graft; $n = 2$). There were 12 type II endoleaks, three of which were treated with coil embolization. Finally, there was one undetermined endoleak. All type I and III endoleaks were treated with additonal stent grafts.

DISCUSSION

Regardless of the treatment method and the use of adjunctive strategies, TAAA repair will continue to be associated with a considerable mortality and morbidity. Conventional TAAA by surgical repair is only applicable to a selected group of patients, as shown in the high rejection rate in the present cohort. Hybrid repair was initially promising for a number of patients who could not tolerate open repair, but has only limited advantages, as it is still a major procedure.[14–16] The use of total endovascular repair has the potential for minimizing the surgical impact on the patient, and allowing treatment of more suitable patients, with promising results.[7,9,10,17–20] Over the years, more difficult anatomies and sicker patients have been treated, which probably explains a number of technical failures and the relatively high mortality/morbidity in this series.

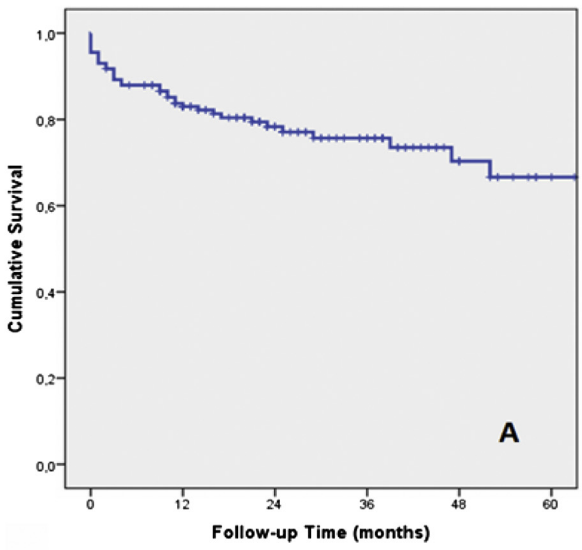
Nevertheless, the results of this 10 year experience with endovascular TAAA repair are promising. Technical success was high (95%), showing that total endovascular repair of TAAA can be successfully completed in a high proportion of patients. Most technical failures were ‘physician failures’ and most (89%) concerned target vessel catheterization/stenting. Technical failures were most commonly observed during the first years of the program. Better pre-operative stent graft planning and avoidance of intra-operative “mistakes” with increasing experience has improved the technical success rate over the last 5 years.

The 30 day operative mortality rate of 7.8%, with an in hospital mortality of 9%, is not appealing for a real “minimally invasive” technique. The impact of the disease and the high risk profile of the patient cohort (84% ASA III/IV, 65% refused for open surgery, 23% ≥ 75 years old) explain these figures. Almost half (47%) of the patients had previous aortic surgery, which increased the technical and clinical challenges associated with the repair. Finally, the learning curve has to be taken into account, and it required some time to implement a team approach including an experienced anesthetist, an interventional scrub nurse, a radiology technician, and at least two experienced operators. Recently, a group from Lille presented their experience with endovascular TAAA repair in 89 patients, reporting similar peri-operative mortality rates (30 day and in hospital mortality of 8.9% and 10%, respectively).

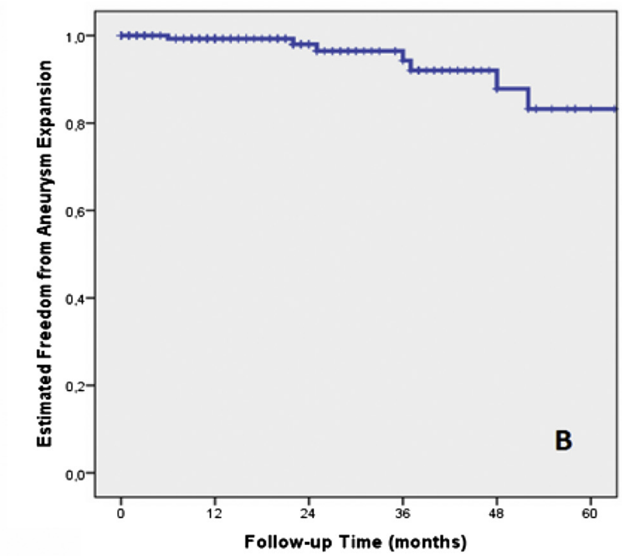
Peri-operative morbidity was not negligible, but lower if compared with open surgery. Cardiac peri-operative complications of 5.4%, pulmonary complications of 3.6%, and severe (>30%) renal function deterioration of 5.4%, with dialysis in only one (0.6%) patient compare favorably with reported open surgery results of large volume centers. Recently, Coselli et al. reported cardiac peri-operative complications in 30.4%, pulmonary complications in 41.1%, and deterioration of renal function requiring temporary or permanent dialysis in 7.4%, from a total of 823 open TAAA repairs within the period 2005–2012.[4]

Peri-operative SCI developed in 15 (9%) patients, with permanent paraplegia in two (1.2%). This rate is in line with other contemporary endovascular series.[7,18,20] To reduce the incidence and impact of SCI, aggressive pre-operative, intra-operative, and post-operative management has been adopted. Stent graft planning aims to routinely maintain LSA and bilateral hypogastric artery perfusion whenever possible. CSF drainage is usually performed in type I, II, and III TAAA, and in patients with previous abdominal aortic surgery. Patients are kept normotensive throughout and after the procedure. Finally, the procedure is performed via open surgical access with the use of purse string sutures to enable quick removal of large sheaths and re-establishment of hypogastric and lower limb circulation as soon as possible. This allows for more collateral circulation to the spinal cord immediately, and reduces the impact of reperfusion injury later.

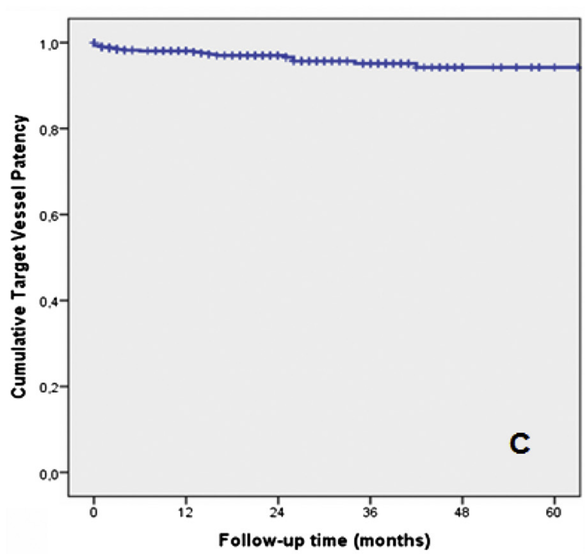
Late estimated survival is similar to other large endovascular TAAA repair series, but could improve with stricter selection of patients.[9,20] In this series, 19 ASA IV patients were treated. Both operative and late mortality in this small group were higher compared with patients scoring ASA III



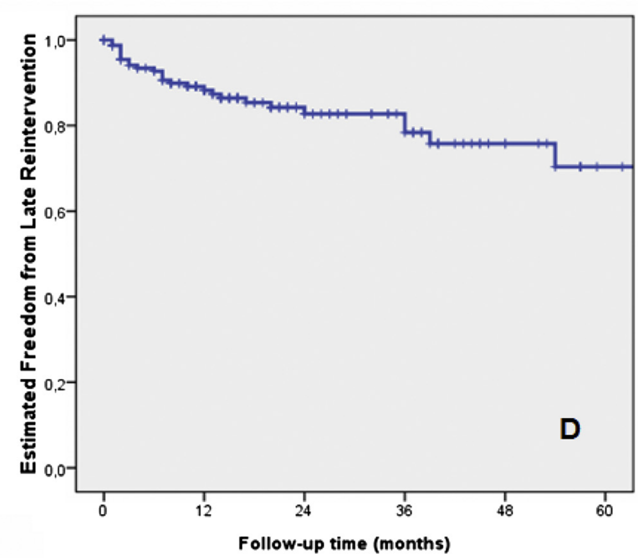
Time (months)	12	24	36	48	60
Patients at risk	113	67	43	21	10
Standard Error (%)	3.0	3.5	3.9	5.2	6.1
Survival (%)	83	78	75.7	70.3	66.6



Time (months)	12	24	36	48	60
Patients at risk	113	66	43	21	10
Standard Error (%)	0.7	1.5	3.0	5.4	6.8
Freedom from aneurysm expansion (%)	99.3	98	94.3	87.9	83.2



Time (months)	12	24	36	48	60
Target vessels at risk	431	253	153	72	33
Standard Error (%)	0.6	0.8	1.2	1.5	1.5
Patency (%)	98	97	95.1	94.2	94.2



Time (months)	12	24	36	48	60
Patients at risk	104	55	36	17	8
Standard Error (%)	2.7	3.5	4.5	5.0	7.0
Freedom from Reinterventions (%)	88.3	82.7	78.4	75.8	70.4

Figure 2. Kaplan—Meier estimate of the cumulative overall patient survival (A), freedom of aneurysm sac expansion (B), target vessel stent patency (C), and freedom of late re-interventions (D).

or less. Obviously, it is difficult to refuse treatment to tertiary referrals and pre-conditioned patients. The approach towards ASA IV patients has nevertheless become stricter, as these patients only rarely seem to benefit from this procedure. On the other hand, it is believed that “healthy” TAAA patients should be considered for endovascular TAAA repair, especially those with suitable anatomy and without connective tissue disease.

The need for late re-intervention appears to be a concern after total endovascular TAAA repair. In this series 17% of the patients required at least one re-intervention within 2 to 3 years of the index procedure. Nevertheless, the

Table 5. Late (>30 days) re-intervention events during follow up.

Re-intervention	*N*
Target vessel bridging stent relining/extension	18
For endoleak	11
- Type Ib endoleak	7
- Type III endoleak	4
For stenosis	7
Iliac stent graft extension (Type Ib endoleak)	4
Proximal stent graft extension (Type Ia endoleak)	3
Coil embolization for Type II endoleak	3
Femoral—femoral crossover bypass	2
Thoracic bridging stent graft for disconnection (Type III endoleak)	2
Target vessel thrombolysis	1
Groin drainage because of infected seroma	1
Laparotomy—lavage—omentoplasty because of stent graft infection	1
Ilio-renal bypass	1
Total	36

majority (>85%) of re-interventions involved minimally invasive endovascular procedures with a high technical success rate (94%). Most of late re-interventions involved correction of the stented visceral vessels either because of endoleak (more common) or, rarely, because of stenosis. This increased tendency for visceral vessel revision may be partly because of the lack of dedicated bridging stent grafts and other ancillary products. Despite the frequent need for re-intervention, the technique seems to work well in terms of target vessel stent patency, remaining around 95% for up to 5 years.

Limitations of the present study include the constant evolution of stent graft technology (both Cook branched stent grafts and bridging covered stents), the learning curve, and also the evolution of the technique in terms of treating more difficult anatomies and older and sicker patients.

CONCLUSIONS

Endovascular TAAA repair, planned and performed by dedicated teams in high volume centers, provides high technical success rates and low peri-operative mortality and morbidity, given the impact of the disease and the high risk profile of the patients treated. The need for re-intervention currently seems to represent the main deficit of the technique over open repair. Overall, mid-term safety and durability as reflected by the absence of late aneurysm rupture and target vessel stent patency is excellent.

CONFLICT OF INTEREST

Eric L.G. Verhoeven has received educational grants and is a consultant for Cook Inc., W.L. Gore & Associates, Siemens and Atrium-Maquet.

FUNDING

None.

REFERENCES

1 Safi HJ, Miller 3rd CC, Huynh TT, Estrera AL, Porat EE, Winnerkvist AN, et al. Distal aortic perfusion and cerebrospinal fluid drainage for thoracoabdominal and descending thoracic aortic repair: ten years of organ protection. *Ann Surg* 2003;**238**:372—80.

2 Cowan Jr JA, Dimick JB, Henke PK, Huber TS, Stanley JC, Upchurch Jr GR. Surgical treatment of intact thoracoabdominal aortic aneurysms in the United States: hospital and surgeon volume-related outcomes. *J Vasc Surg* 2003;**37**:1169—74.

3 Schepens MA, Heijmen RH, Ranschaert W, Sonker U, Morshuis WJ. Thoracoabdominal aortic aneurysm repair: results of conventional open surgery. *Eur J Vasc Endovasc Surg* 2009;**37**:640—5.

4 Lemaire SA, Price MD, Green SY, Zarda S, Coselli JS. Results of open thoracoabdominal aortic aneurysm repair. *Ann Cardiothorac Surg* 2012;**1**:286—92.

5 Chuter TA, Gordon RL, Reilly LM, Goodman JD, Messina LM. An endovascular system for thoracoabdominal aortic aneurysm repair. *J Endovasc Ther* 2001;**8**:25—33.

6 Greenberg RK, Haulon S, Lyden SP, Srivastava SD, Turc A, Eagleton MJ, et al. Endovascular management of juxtarenal aneurysms with fenestrated endovascular grafting. *J Vasc Surg* 2004;**39**:279—87.

7 Greenberg RK, Lu Q, Roselli EE, Svensson LG, Moon MC, Hernandez AV, et al. Contemporary analysis of descending thoracic and thoracoabdominal aneurysm repair: a comparison of endovascular and open techniques. *Circulation* 2008;**118**:808—17.

8 Muhs BE, Verhoeven EL, Zeebregts CJ, Tielliu IF, Prins TR, Verhagen HJ, et al. Mid-term results of endovascular aneurysm repair with branched and fenestrated endografts. *J Vasc Surg* 2006;**44**:9—15.

9 Roselli EE, Greenberg RK, Pfaff K, Francis C, Svensson LG, Lytle BW. Endovascular treatment of thoracoabdominal aortic aneurysms. *J Thorac Cardiovasc Surg* 2007;**133**:1474—82.

10 Verhoeven E, Tielliu IF, Zeebregts CJ, Bekkema F, Vourliotakis G, Ritter W, et al. Results of endovascular repair of TAAA in the first 50 patients. *Zentralbl Chir* 2011;**136**:451—7.

11 Verhoeven EL, Vourliotakis G, Bos WT, Tielliu IF, Zeebregts CJ, Prins TR, et al. Fenestrated stenafting for short-necked and juxtarenal abdominal aortic aneurysm: an 8-year single-centre experience. *Eur J Vasc Endovasc Surg* 2010;**39**:529—36.

12 Verhoeven EL, Katsargyris A, Fernandes EFR, Bracale UM, Houthoofd S, Maleux G. Practical points of attention beyond instructions for use with the Zenith fenestrated stenaft. *J Vasc Surg* 2014;**60**:246—52.

13 Fillinger MF, Greenberg RK, McKinsey JF, Chaikof EL. Reporting standards for thoracic endovascular aortic repair (TEVAR). *J Vasc Surg* 2010;**52**:1022—33.

14 Bockler D, Kotelis D, Geisbusch P, Hyhlik-Durr A, Klemm K, von Tengg-Kobligk H, et al. Hybrid procedures for thoracoabdominal aortic aneurysms and chronic aortic dissections — a single center experience in 28 patients. *J Vasc Surg* 2008;**47**:724—32.

15 Black SA, Wolfe JH, Clark M, Hamady M, Cheshire NJ, Jenkins MP. Complex thoracoabdominal aortic aneurysms: endovascular exclusion with visceral revascularization. *J Vasc Surg* 2006;**43**:1081—9.

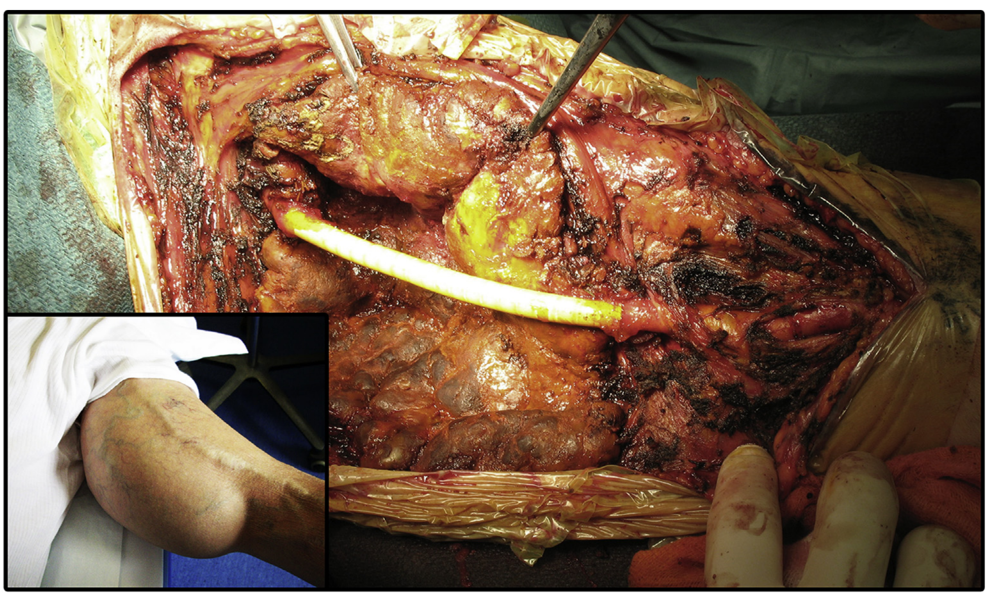
16 Rosset E, Ben Ahmed S, Galvaing G, Favre JP, Sessa C, Lermusiaux P, et al. Editor's choice-hybrid treatment of thoracic, thoracoabdominal, and abdominal aortic aneurysms: a multicenter retrospective study. *Eur J Vasc Endovasc Surg* 2014;**47**:470—8.
17 Anderson JL, Adam DJ, Berce M, Hartley DE. Repair of thoracoabdominal aortic aneurysms with fenestrated and branched endovascular stent grafts. *J Vasc Surg* 2005;**42**: 600—7.
18 Chuter TA, Rapp JH, Hiramoto JS, Schneider DB, Howell B, Reilly LM. Endovascular treatment of thoracoabdominal aortic aneurysms. *J Vasc Surg* 2008;**47**:6—16.
19 Ferreira M, Lanziotti L, Monteiro M. Branched devices for thoracoabdominal aneurysm repair: early experience. *J Vasc Surg* 2008;**48**:30S—6S.
20 Guillou M, Bianchini A, Sobocinski J, Maurel B, D'Elia P, Tyrrell M, et al. Endovascular treatment of thoracoabdominal aortic aneurysms. *J Vasc Surg* 2012;**56**:65—73.

Eur J Vasc Endovasc Surg (2015) 49, 531

COUP D'OEIL

Giant True Brachial Artery Aneurysm After Hemodialysis Fistula Closure

M. Marconi, D. Adami *
Pisa, Italy



We report a case of a giant true brachial artery aneurysm in a 61 year old patient with a previous radiocephalic arteriovenous fistula for haemodialysis. The fistula had been ligated 12 years previously after successful renal transplantation. Despite the huge size of the aneurysm (20 × 10 × 9 cm), the patient did not complain of any compressive or ischemic symptoms. The aneurysm was surgically excluded and replaced with a 6 cm expanded polytetrafluoroethylene brachio-brachial bypass. There were no post-operative or late complications, and the graft was patent after 60 months of follow up.

* Corresponding author.
E-mail address: d.adami@ao-pisa.toscana.it (D. Adami).

http://dx.doi.org/10.1016/j.ejvs.2015.02.005